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IS : 6134 (Part IX) - 1981
(Reaffirmed 2003)

Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART IX BACKWARD-WAVE OSCILLATOR TUBE 'O' TYPE

UDC 621·385·633 : 621·317·3

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NEW DELHI 110002

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Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART IX BACKWARD-WAVE OSCILLATOR TUBE 'O' TYPE

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Indian Standard

METHODS OF MEASUREMENT OF ELECTRICAL CHARACTERISTICS OF MICROWAVE TUBES

PART IX BACKWARD-WAVE OSCILLATOR TUBE 'O' TYPE

0. FOREWORD

0.1 This Indian Standard (Part IX) was adopted by the Indian Standards Institution on 23 June 1981, after the draft finalized by the Electron Tubes Sectional Committee had been approved by the Electronics and Telecommunication Division Council.

0.2 This standard covers the methods of measurement of electrical characteristics of backward-wave oscillator tubes ' 0 ' type.

0.3 The theoretical working of backward-wave oscillator tube is given in Appendix A.

0.4 Methods of measurement of different types of microwave tubes are being covered in a series of standards consisting of the following individual parts:

Part I	Common to all microwave tubes
Part II	Oscillator tubes
Part III	Amplifier tubes
Part IV	Magnetrons
Part V	Parasitic noise
Part VI	Low power oscillator klystrons
Part VII	High power klystrons
Part VIII	Gas-filled microwave switching devices
Part IX	Backward-wave oscillator tube ' 0 ' type
Part X	Crossed-field amplifier tubes

0.5 While preparing this standard, assistance has been derived from IEC Pub 235-8 (1972) "Measurement of the electrical properties of microwave tubes: Part 8 Backward-wave oscillator tubes ' 0 ' type" issued by International Electrotechnical Commission.

0.6 In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard (Part IX) specifies the methods of measurement of electrical characteristics of backward-wave oscillator tube ' 0 ' type.

2. TERMINOLOGY

2.1 For the purpose of this standard, the terms and definitions given in IS : 1885 (Part IV/Sec 3) - 1970† shall apply.

3. GENERAL REQUIREMENTS AND PRECAUTIONS

3.1 The measurement circuit generally used is shown in Fig 1. It comprises:

a) the supply to the tube being measured, with modulating devices (usually 50 or 60 Hz) for the voltages of the slow-wave structure or first anode and of the control grid. The modulating signal is also used as a deflection voltage for the oscilloscope.

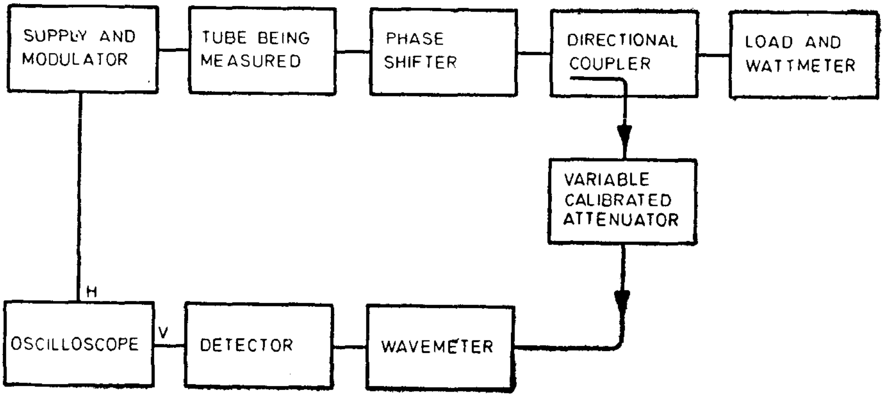

FIG. 1 GENERAL CIRCUIT DIAGRAM

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*Rules for rounding off numerical values (*revised*).

†Electrotechnical vocabulary: Part IV Electron tubes, Section 3 Microwave tubes.

b) an absorption wavemeter of sufficiently high Q to enable the determination of the frequency in the electronic tuning band as a function of the slow-wave-structure voltage by observation of the 'pip' produced on the power curve shown on the oscilloscope.
c) a phase shifter to adjust the reflection factor of the load to the desired value and to vary the phase; in some cases it may be desirable that the phase shifter be motor-driven continuously through all phases.
d) a conventional power measuring device.
e) a calibrated variable attenuator connected to a directional coupler.

3.1.1 For the measurements described, the measuring frequency or frequencies shall be indicated for each type of tube. For certain measurements (for example, measurement of discontinuity of frequency) the whole range of frequency shall be analyzed in a continuous manner while the stated reflection coefficient of the load is continuously varied through all possible phases.

3.1.2 After the cathode has been heated for a stated time, the voltages shall be applied in the order indicated by the manufacturer and in accordance with his instructions. In particular, the indicated degree of supply stabilization shall be used.

3.1.3 The cathode is the reference point for measuring electrode voltages, although it is not necessary for the cathode to be at earth potential. In order to avoid the need for a dc break in the *rf* output circuit, the slow-wave structure is usually earthed so that the cathode is at negative potential with respect to earth.

3.2 The following precautions must also be taken for backward-wave oscillators incorporating unshielded permanent magnet focusing:

a) The safe spacing of the tube in relation to any adjacent magnetic or ferromagnetic parts shall be observed so as to avoid distortion of the characteristics of the tube and possible permanent demagnetizing effects.
b) Non-magnetic tools must be used in inserting (or removing) the tube into the measurement circuit.

4. METHODS OF MEASUREMENT

4.1 Mean RF Output Power

4.1.1 Provision of **10.1.1** of IS : 6134 (Part I)-1978* shall apply.

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*Methods of measurement on microwave tubes: Part I Common to all microwave tubes [*Superseding* IS : 6134 (Part I/Sec 1)-1971 and IS : 6134 (Part I/Sec 2)-1972)].

4.2 Tuning Range

4.2.1 Provision of **B-1** shall apply, but this shall not be applicable as regards the mode change.

4.2.2 The circuit in Fig. 1 is used. The slow-wave-structure voltage is modulated by a low-frequency (50 Hz) signal of stated peak-to-peak amplitude and the resulting frequency excursion is measured. This frequency excursion is the frequency tuning range.

NOTE — In some cases the slow-wave-structure voltage may be varied manually over a stated total range.

4.2.3 *Method of Measurement of Tuning-Range Power Ratio* — The tube is connected as shown in Fig. 1 and is operated in accordance with the manufacturer's instructions.

With all other voltages maintained constant, the voltage of the slow-wave structure is changed to cover the stated tuning range and the variations in the output power are measured.

The result of the measurement is the ratio of the maximum to the minimum value of output power in the stated tuning range. It may be expressed in decibels.

NOTE — It is also possible to sweep the voltage of the slow-wave structure to cover the stated tuning range and to determine the ratio from the curve displayed on a calibrated oscilloscope.

4.3 Electronic Tuning Sensitivity

4.3.1 Provisions of **B-2** shall apply. The variable parameter is the slow-wave structure voltage.

4.4 Electronic Tuning Hysterosis

4.4.1 Provisions of **B-3** shall apply. The variable parameter is the slow-wave structure voltage.

4.5 Frequency-Pushing Figure of a Stated Electrode

4.5.0 Provisions of **4.2** of IS : 6134 (Part II)-1973* shall apply in addition to the following.

4.5.1 The variable quantity is the cathode current. The required variation of cathode current is achieved by adjustment of the stated electrode voltage. The pushing figure is expressed in MHz per ampere of cathode current.

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*Methods of measurement on microwave tubes: Part II Oscillator tubes.

4.6 Frequency-pulling Figure

4.6.1 Provision of **4.1** of IS : 6134 (Part II)-1973* shall apply.

4.7 Discontinuity of Frequency Band

4.7.1 The tube is operated in the circuit (*see* Fig. 1) under stated conditions. The slow-wave-structure voltage is modulated by a signal at 50 or 60 Hz so that the desired frequency band is swept, and the reflection, coefficient is varied over all phases at the stated magnitude. The frequency/power curve is displayed on the oscilloscope and the 'pip' of the wavemeter appears on this curve. By varying the frequency of the wavemeter those frequencies or frequency bands in which the 'pip' of the wavemeter disappears are found. These correspond to the discontinuities in the frequency band.

NOTE — The loaded Q of the wavemeter should be such that the frequency excursion through the 'pip' does not exceed a stated value.

4.8 Conformance of the Electronic Tubing Characteristic

4.8.1 The tube is operated in the circuit (*see* Fig. 1) under stated conditions.

4.8.2 The slow-wave-structure voltages, corresponding to stated frequencies are measured. These voltages should fall between stated values.

4.9 Amplitude Modulation by a Stated Electrode

4.9.1 The tube is operated under stated conditions and the output power is measured. The voltage on the stated electrode is measured and reduced until the output power diminishes by 3 dB (or 6 dB), and the voltage on the stated electrode is measured again.

4.9.2 The amplitude modulation is expressed as the change in voltage measured at the stated electrode, expressed as a percentage of the original values.

4.10 Blockage of Oscillations by a Control Electrode

4.10.1 With the tube operating under the stated conditions, the voltage at the control electrode is first measured, and is then adjusted until the tube ceases to oscillate. The control electrode voltage is again measured. The result of the measurement is the change in voltage, expressed in volts.

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*Methods of measurement on microwave tubes: Part II Oscillator tubes.

4.11 Frequency Drift Under Pulse Operation

4.11.1 *Theory* — When the voltage of the slow-wave structure of a backward-wave oscillator tube is suddenly altered, the equilibrium that existed is destroyed. A certain time delay is necessary in order to obtain a new electron-ion or mechanical-thermal equilibrium corresponding to the new operating conditions.

When the voltage of the slow-wave structure is modulated by rectangular pulses (*see* Fig. 2A) the wave of frequency variation that results does not have exactly the same rectangular form (*see* Fig. 2B). The frequency '*F*' corresponding to the slow-wave-structure voltage 'V_L' is obtained only after a certain time delay.

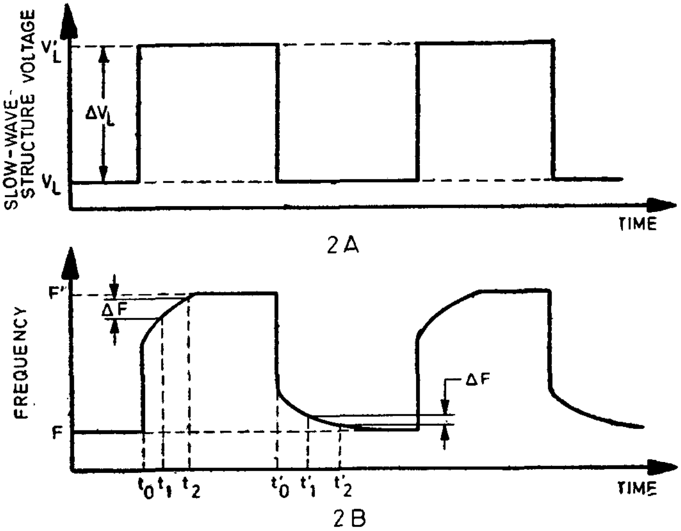

FIG. 2 MEASUREMENT OF PULSE FREQUENCY DRIFT

4.11.2 *Basic Circuit* — The arrangement shown in Fig. 3 is used. The modulation pulses of the slow-wave-structure voltage are used for the synchronization of the horizontal scanning of the oscilloscope.

The signal resulting from the mixture of the frequency of the backward-wave oscillator tube and the frequency of a local oscillator is amplified and then passed into a discriminator, which converts the frequency variations into amplitude variations that can be observed on a previously calibrated oscilloscope. A typical oscilloscope display is shown in Fig. 2B.

4.11.3 *Measurement* — With the tube operating under the stated conditions and the stated amplitude of the voltage pulse (or for a pulse voltage amplitude to produce the desired frequency deviation) applied to the slow-wave structure, the frequency shift *versus* time is displayed as shown in Fig. 3 and the time or frequency shift is measured as required.

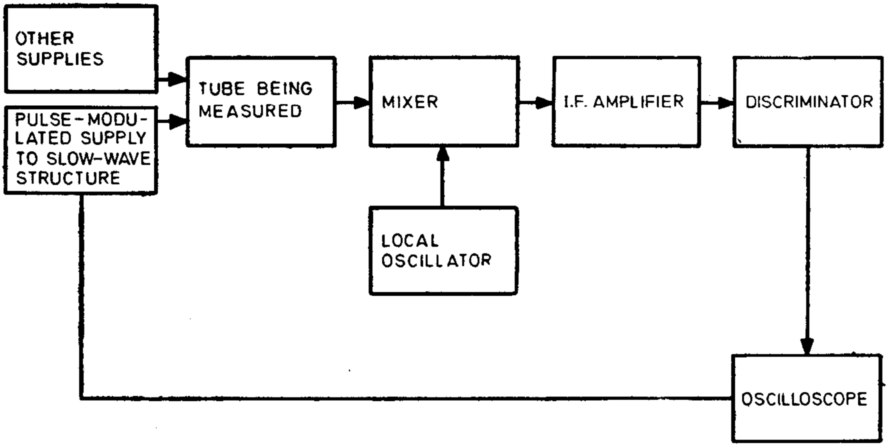

FIG. 3 BLOCK DIAGRAM OF THE CIRCUIT FOR THE MEASUREMENT OF PULSE FREQUENCY DRIFT

On the graph in Fig. 2B, t_0 corresponds to the start of the modulation pulse on the slow-wave-structure voltage, and the interval t_0 to t_1 is fixed in relation to the application requirements of the oscillators – for example at about 100 μ s.

The result of the measurement can be expressed either as a frequency drift ($\triangle F$) for a stated period of time t_1 to t_2, for example 400 μs, or as a period of time for a stated frequency drift. In the latter case, the frequency drift is measured from t_1 and result of the measurement is $t_2 - t_1$.

The result may also be expressed as the ratio of the frequency drift in a stated time period (or the time required to traverse a stated frequency drift) to the amplitude of the applied voltage pulse.

4.11.4 *Precautions* — The level part of the pulse of the voltage of the slow-wave structure during which the measurement of frequency drift is made, should be stable, since the drift being measured is of the order of a few tens of kHz.

4.12 Post-Tuning Frequency Drift

4.12.1 The tube is connected as shown in Fig. 4, and is typically operated at the low end of the band until the frequency is stabilized. The tube is then switched to the high end of the band. The instantaneous frequency is noted and the subsequent frequency change is recorded. This is the post-tuning frequency drift. Typical values are 1 to 3 MHz.

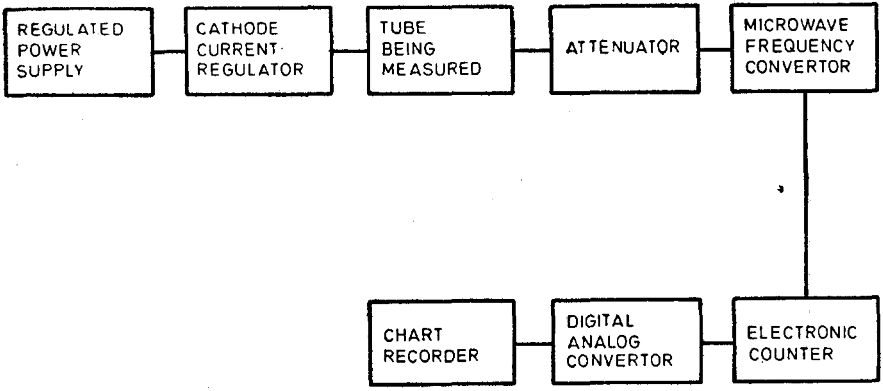

FIG. 4 BLOCK DIAGRAM OF THE CIRCUIT FOR THE MEASUREMENT OF TURN-ON FREQUENCY DRIFT AND POST-TUNING FREQUENCY DRIFT

NOTE — This drift is influenced by the thermal expansion properties of the tube and is affected by the variations of the dissipated power that are a consequence of the electronic tuning properties of the device.

4.13 Turn-on Frequency Drift

4.13.1 The tube is connected as shown in Fig. 4. The filament voltage is applied for the stated period. The anode and slow-wave structure voltages are turned on and adjusted for normal power output and at some frequency in the operating band of the tube. The frequency of the tube is then recorded at suitable times in a period sufficient to result in equilibrium. The result of the measurement is the total change in frequency from initial to final measurement and typical values are 1 to 2 MHz.

4.14 Sensitivity to External Magnetic Effects

4.14.1 The circuit shown in Fig. 1 is used.

4.14.2 Ferromagnetic material (for example, mild steel plate) of stated dimensions, or magnetic materials (for example, a magnet of stated steel grade) of stated dimensions and magnetized to saturation, is moved around the tube at the distance indicated by the manufacturer.

4.14.3 The maximum variations in RF output power, and also any frequency variations, are measured.

4.14.4 These variations are a measure of the sensitivity of the tube to external magnetic effects.

4.15 Temperature Coefficient of Frequency

4.15.1 Provisions of **4.3** of IS : 6134 (Part II)-1973* shall apply.

APPENDIX A

(*Clause* 0.3)

A-1. BACKWARD-WAVE OSCILLATOR (BWO) TUBE

A-1.1 The BWO consists of an electron gun (consisting of a cathode, a grid and an accelerator, an RF circuit (delay line), an attenuator and a collector (*see* Fig. 5).

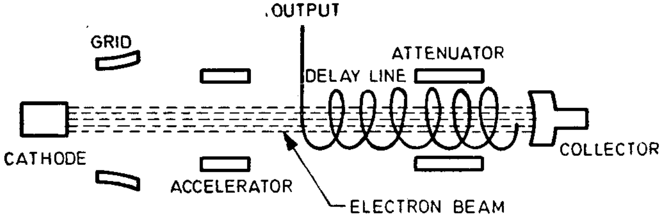

FIG. 5 SCHEMATIC DIAGRAM OF A BACKWARD WAVE OSCILLATOR ('0' TYPE)

A-1.2 The electron gun is the source of the electron beam. The electrons are emitted from an indirectly heated cathode and accelerated into a high density beam by the accelerator.

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*Methods of measurement on microwave tubes: Part II Oscillator tubes.

A-1.3 The electron beam passes along the RF circuit (delay line and the popular form is helix) which is a slow wave structure and it slows down the RF wave down to the velocity of the electron beam for interaction between them.

A-1.4 The attenuator situated at the end of the slow wave circuit, prevents reflected energy from interfering with the wave being generated.

A-1.5 The electrons that no longer figure in energy transfer through interaction are collected by the collector.

A-1.6 When power is applied to the backward-wave oscillator (*see* Fig. 6), electrons emitted by the cathode form a beam whose density is determined by the beam potential between the cathode, delay line (helix) and collector.

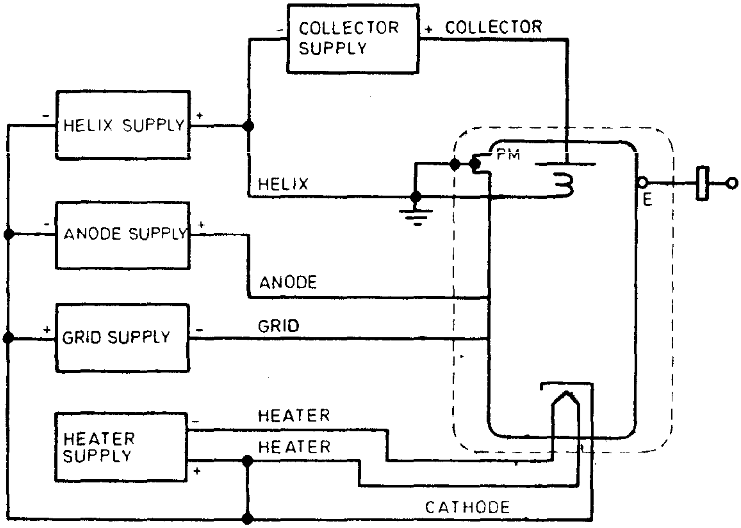

FIG. 6 SCHEMATIC DIAGRAM OF AN 0-TYPE BACKWARD WAVE OSCILLATOR WITH EXTERNAL POWER APPLIED

At this time, inherent tube noise produces waves which are propagated from the collector end of the tube down the delay line to the cathode-output end of the tube. The noise waves travelling in an axial direction down the delay line at the beam velocity excite electron bunching at specific RF rate. This bunching augments the waves with an axial velocity equal to the electron velocity and it effectively causes RF oscillations, provided that the dc beam current, and thus the RF wave current, is of sufficient magnitude. A too low starting current induces an RF wave smaller than the one which produced the electron bunching and thus will cause the RF wave to die out. As the current is increased in a backward-wave oscillator, the induced wave becomes larger, eventually as large as the original existing wave. Beyond this, oscillations are self-sustaining.

A-1.7 At the cathode end of the RF circuit, the wave components encounter an output coupling element. This element extracts the waves from the slow wave circuit for application through a transmission line to the load.

A-1.8 The frequency of oscillation for the '0' type backward wave oscillator is approximately proportional to the log of the voltage applied between the cathode and the delay line.

APPENDIX B

(*Clauses* 4.2.1, 4.3.1 *and* 4.4.1)

METHOD OF MEASUREMENT OF TUNING

B-1. FREQUENCY TUNING RANGE

B-1.1 This is obtained by measuring the characteristics of power output *versus* frequency. It is preferable that the required frequency range be obtained by use of a single oscillatory mode. However, where a change of mode is permissible, this change should not be considered as constituting a discontinuity of frequency tuning range.

B-2. TUNING SENSITIVITY (MECHANICAL OR ELECTRONIC)

B-2.1 The tuning sensitivity may be obtained from a measurement of frequency change with a stated variation of the tuning control (mechanical or electronic) or, alternatively, as a measurement of tuning control variation for a stated frequency change.

B-2.2 As the tuning sensitivity is not necessarily uniform over the required tuning range, it is recommended that an indication be given as to which part of the range is used in making the measurement, for example, a stated frequency spread centred at the half-power point, over the linear range or in the small-signal range.

B-3. ELECTRONIC TUNING HYSTERESIS

B-3.1 The tube is operated under stated conditions at the reference frequency. The electronic tuning control voltage is varied by the application of a suitable alternating sweep voltage of stated amplitude and frequency.

INDIAN STANDARDS ON ELECTRON TUBES

IS:

1885 (Part IV/Sec 1)-1973 Electrotechnical vocabulary: Part IV Electron Tubes, Section 1 Common terms (*first revision*)
1885 (Part IV/Sec 2)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 2 X-ray tubes (*first revision*)
1885 (Part IV/Sec 3)-1970 Electrotechnical vocabulary: Part IV Electron tubes, Section 3 Microwave tubes
1885 (Part IV/Sec 4)-1970 Electrotechnical vocabulary: Part IV Electron tubes, Section 4 Cathode-ray tubes
1885 (Part IV/Sec 5)-1972 Electrotechnical vocabulary: Part IV Electron tubes, Section 5 Pulse terms
1885 (Part IV/Sec 6)-1972 Electrotechnical vocabulary: Part IV Electron tubes, Section 6 Noise in microwave tubes
1885 (Part IV/Sec 7)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 7 Camera tubes
1885 (Part IV/Sec 8)-1973 Electrotechnical vocabulary: Part IV Electron tubes, Section 8 Photosensitive devices
2032 (Part IX)-1969 Graphical symbols used in electrotechnology: Part IX Electron tubes (other than microwave tubes)
2032 (Part XIII)-1971 Graphical symbols used in electrotechnology: Part XIII Microwave tubes
2597 (Part I)-1964 Code of practice for the use of electron tubes: Part I Commercial receiving tubes
2597 (Part II)-1967 Code of practice for the use of electron tubes: Part II Special quality receiving tubes
2597 (Part III)-1969 Code of practice for the use of electron tubes: Part III Transmitting and industrial tubes
2597 (Part IV)-1970 Code of practice for the use of electron tubes: Part IV Cathode-ray tubes
2597 (Part V)-1971 Code of practice for the use of electron tubes: Part V Rectifiers and thyratrons
2684 (Part I)-1972 Dimensions of electron tubes: Part I Miniature '9-pin type' (*first revision*)
2684 (Part II)-1972 Dimensions of electron tubes: Part II Miniature '7-pin type' (*first revision*)
2684 (Part III)-1971 Dimensions of electron tubes: Part III Octal base type
2684 (Part IV)-1971 Dimensions of electron tubes: Part IV Magnoval base type
2684 (Part V)-1972 Dimensions of electron tubes: Part V Loctal base type
3154-1965 X-ray tubes, diagnostic type
4096-1973 Method of measurement of optical focal spot size of X-ray tubes (*first revision*)
*4147-1967 Method of measurements on conventional receiving electron tubes
4579-1968 Method of measurements on television picture tubes
4697-1968 Method of measurements on Geiger Muller counter tubes
5323-1969 Letter symbols and abbreviations for electron tubes
*5627-1970 Methods of measurements on cathode-ray display tubes
5840 (Part I)-1970 Dimensions of cathode-ray tubes: Part I Tube outlines
5840 (Part II)-1970 Dimensions of cathode-ray tubes: Part II Base type
5840 (Part III)-1970 Dimensions of cathode-ray tubes: Part III EHT terminals

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*Under revision

6134 (Part I)-1978 Methods of measurements on microwave tubes: Part I Common to all microwave tubes [*Superseding* IS : 6134 (Part I/Sec 1)-1971 *and* IS : 6134 (Part I/Sec 2)]

*6134 (Part II)-1973 Methods of measurement on microwave tubes: Part II Oscillator tubes

*6134 (Part III)-1973 Methods of measurement on microwave tubes: Part III Amplifier tubes

6134 (Part IV)-1977 Methods of measurement on microwave tubes: Part IV Magnetrons

6134 (Part V)-1980 Methods of measurement on microwave tubes: Part V Parasitic noise

6134 (Part VI)-1981 Methods of measurement of electrical characteristics of microwave tubes: Part VI Low-power oscillator klystrons

6134 (Part VII)-1981 Methods of measurement of electrical characteristics of micro wave tubes: Part VII High-power klystrons

6134 (Part VIII)-1981 Methods of measurement of electrical characteristics of microwave tubes: Part VIII Gas-filled microwave switching devices

6134 (Part IX)-1981 Methods of measurement of electrical characteristics of microwave tubes: Part IX Backward-wave oscillator tube 'O' type

6134 (Part X)-1981 Methods of measurement of electrical characteristics of microwave tubes: Part X Crossed-field amplifier tubes

6136-1971 Basic requirements for cathode-ray tubes

*6214-1971 Phosphors for cathode-ray tubes

6567-1972 Radiation protection for an X-ray tube in a protective tube-housing operating between 10 and 400 kV

6568-1972 Implosion protection for TV picture tubes

6576-1972 Methods of measurements on gas-filled cold cathode indicator tubes

6577-1972 Methods of measurements on gas-filled cold cathode voltage stablizing and voltage reference tubes

6757-1972 Dimensions for high tension cable terminations for X-ray tubes

6758-1972 Dimensions for high tension receptacles for X-ray tubes

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7144-1973 Methods of measurements on camera tubes

7146 (Part I)-1973 Methods of measurements on photosensitive devices: Part I Basic considerations

7146 (Part II)-1974 Methods of measurements on photosensitive devices: Part II Photo-tubes

7146 (Part III)-1974 Methods of measurements on photosensitive devices: Part III Photoconductive cells for use in the visible spectrum

7146 (Part IV)-1974 Methods of measurements on photosensitive devices: Part IV Photomultipliers

8319 (Part I)-1977 Dimensions of indicator tubes: Part I Tube, Type 1

8319 (Part II)-1977 Dimensions of indicator tubes: Part II Tube, Type 2

8319 (Part III)-1973 Dimensions of indicator tubes: Part III Tube, Type 3

8319 (Part IV)-1979 Dimensions of indicator tubes: Part IV Tube, Type 4

8441-1977 Methods of measurements on incidental X-radiation from electron tubes

9383 (Part I)-1979 Dimensions of sign indicator tubes: Part I Tube, Type 1

9383 (Part II)-1979 Dimensions of sign indicator tubes: Part II Tube, Type 2

9492-1980 Methods of measurement of RF/microwave leakage from integral circuit electron tubes

9883-1981 Photometric and colorometric methods of measurements of the eight emitted by a cathode-ray tube screen

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*Under revision

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

Quantity	*Unit*	*Symbol*
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

Quantity	*Unit*	*Symbol*
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

Quantity	*Unit*	*Symbol*	*Definition*
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = 1 N.m
Power	watt	W	1 W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

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